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ENGINEERING.—*The work of Joseph Henry in relation to applied science and engineering.*[1] ARTHUR E. KENNELLY.[2] (Communicated by L. B. TUCKERMAN.)

The pioneer work of Joseph Henry in physics, and especially in its department of electromagnetics, has justly claimed the principal attention of his biographers and students. Certain aspects of Henry's work in the physics of electromagnetic induction were the theme of that fine presentation last year by President J. S. Ames of the Johns Hopkins University, in the first Joseph Henry lecture of this series. Henry also accomplished, however, so much in applied physics, that without detracting in the least from his fame as a pure scientist and researcher in basic physics, it seems proper to consider, at this time, his achievements in relation to applied science and engineering.

As it is sometimes difficult to distinguish between basic and applied science, when considering the manifold occupations and accomplishments of a scientific pioneer like Henry, we may be permitted to consider as basic those scientific studies directed to the development of a field of knowledge *per se*; and as applied science or engineering, those studies directed to utilities, as well as to the field itself. So interwoven, however, are basic and applied science, and especially in physics, that the distinction between them may sometimes be reduced to mere differences in the attitude of the researcher's mind. One and the same piece of scientific research may be regarded as either basic, or applied, or both, according as the researcher directed his mind to the field of knowledge itself, or to its utilization, or to both.

[1] An address, the second Joseph Henry lecture, delivered before the Philosophical Society of Washington on April 23, 1932. Received April 25, 1932.

[2] Professor Emeritus of Electrical Engineering, Harvard University and the Massachusetts Institute of Technology.

Henry's accomplishments in applied science are notable in the following fields:

I. Civil Engineering.
   Surveying and Geodetics.
II. Electrical Engineering.
   (*a*) Lifting electromagnets.
   (*b*) Electromagnetic telegraphy.
   (*c*) Elementary electromagnetic motors.
   (*d*) Lightning protection.
   (*e*) Electroballistics.
III. Mechanical Engineering.
   (*f*) Building stone tests.
IV. Acoustical Engineering.
   (*g*) In buildings.
   (*h*) In fog-signalling.
V. Illumination Engineering.
   (*i*) In light-house development.
VI. Meteorological Engineering.
   (*j*) Forecasting from telegraph bulletins.

It may be noted that among the 148 publications appearing in the *List of Professor Henry's Scientific Papers*, printed in the Annual Report of the Smithsonian Institution for 1878 and the Bulletin of the Philosophical Society of Washington, Vol. II, nearly forty relate to scientific applications.

SURVEYING AND GEODETICS

In 1825, New York State appointed commissioners to survey the route for a state road from the Hudson River to Lake Erie, a distance of over 500 km. Henry was appointed an engineer on this survey. The route he followed was from Kingston, near West Point, on the Hudson, to Portland Harbor on Lake Erie. He acquitted himself so well in this survey, that an effort was made to have him appointed permanently as state engineer. In 1829, he read a paper,[3] published in the Transactions of the Albany Institute, which is a topographical report covering a considerable part of the state of New York, giving tables of distances and elevations along various routes. His paper gives a clear description of the topography of the country along these routes. It states:

> "The elevations in Table No. 1, between the Hudson River and Bath, are from the survey of William Morell, Esq. The remaining elevations of this Table, as well as those in No. 2, are from the personal survey of the writer of this article."

[3] *Topographical sketch of the State of New York designed chiefly to show the general elevations and depressions of its surface.* Bibliography 8, I: 8–36. Trans. Albany Inst., I: 87–112. The bibliography is at the end of the paper.

These levelling surveys had to be carried over some very difficult stretches of country, including sections of what was, at that time, primeval forest. Henry seems to have taken so much interest in this work that it may have been a matter of good fortune for both basic and applied science, when he was diverted from the profession of engineering by the vacancy of the Chair of Mathematics and Natural Philosophy in the Albany Academy.

ELECTRICAL ENGINEERING

The Traction or Sustaining Electromagnet

Sturgeon, in England, had announced, in 1825, the production of the first horse-shoe electromagnet. It consisted of a bar of soft iron bent into horse-shoe form, insulated on its surface by a coat of varnish,

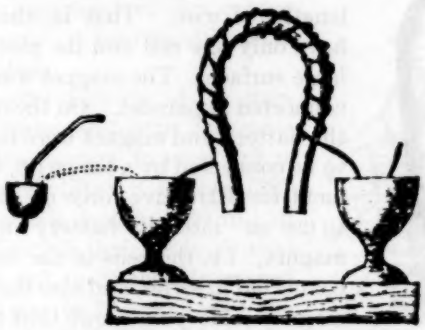

Figure 1.—Sturgeon's electromagnet.

and with bare copper wire wound over it in separate spires. When a voltaic current was passed through the copper wire, the horseshoe became magnetized, and would lift an iron rod laid across its poles.

The laws controlling the force of attraction between the electromagnet and its soft iron keeper, or armature, are complicated and were not worked out in detail for practical applications until many years later. They involve a combination of electric current in the electric wire circuit and of magnetic current or flux in the magnetic circuit.

Henry, experimenting with electromagnets at Albany, N. Y. in the years 1828–1831, succeeded in establishing certain fundamental principles, as to the conditions in both the electric and magnetic circuits, for securing the maximum attractive force from a given horseshoe electromagnet. At the same time, he greatly improved the winding on the magnet by using insulated wire in many close turns. At that time, of course, there were no instruments for measuring electric

current. He made a series of electromagnetic measurements with three controlled elements; viz:

(*a*) the number and the size of the voltaic cells in the exciting circuit of the electromagnet,
(*b*) the length of extra copper wire introduced into this circuit,
(*c*) the number of series or parallel windings on the electromagnet.

Under these controlled variations, he measured the attractive force, in pounds weight, exerted by the magnet.

In coöperation with Dr. Ten Eyck, he showed, from a number of such measurements, that the greatest attractive force or lifting power[4] could be obtained from a horseshoe electromagnet by the use of a "quantity battery" together with a "quantity winding" on the magnet, provided that the battery and magnet were close together and connected by short lengths of wire. That is, the battery should have only one cell and its plates should be of large surface. The magnet windings should be connected in parallel. On the other hand, when the battery and magnet were far apart and had to be connected by a long wire, the best arrangement for attractive force on the armature was to use an "intensity battery" and an "intensity magnet," i.e. the cells of the battery should be connected in series, and also the windings of the magnet. He points out that this combination has a bearing upon the problem of an electromagnetic telegraph. If, however, an intensity magnet has to be used, with all its turns in series, then for best tractive effort an intensity battery should be placed in the circuit, whether the connecting wires between them are short or long.

Figure 2.—Henry's intensity electromagnet.

All of these principles, enunciated by Henry, more than a hundred years ago, are still fundamentally correct. The terminology, however, has been greatly changed, partly through the widespread knowledge of Ohm's law ($I = E/R$) of current in an electric circuit. Dr. Ohm had already published, in Berlin, his essay containing that law[5] in 1827, but the publication received very little attention, and did not find its way into text books on physics until some twenty years later. It did not come into electrical applications until after 1840, in the early de-

[4] Bibliography 8, I: 37–53. Silliman's Am. Jour. Sci. **19**: 400–408. Jan. 1831.

[5] *Die galvanische Kette mathematisch bearbeitet.* Georg Simon Ohm, Professor of Physics at Munich, Berlin 1827.

velopment of telegraphy, and after instruments had been produced for measuring electromotive force, resistance, and current. The above mentioned results which Henry published in 1831, were far in advance of the knowledge in electromagnetics at that time.

In one set of measurements he describes his electromagnet as made of a cylindrical bar of soft iron 1/4 inch (0.64 cm.) in diameter, wound with about 8 feet (2.4 m.) of insulated winding with perhaps 100 turns. When this winding was excited by one copper-zinc voltaic cell with plates of 28 sq. in. (180 sq. cm.) immersed in dilute acid, the weight lifted by the magnet was 4½ lbs. (2 kg.). When a length of 1060 feet (320 m.) of copper bell wire 0.045 inch (1.14 mm.) in diameter was inserted in the circuit between voltaic cell and magnet, the lifting power of the magnet fell to about half an ounce (14 gm.) The resistance of the length of copper specified would today be about 8.8 ohms; but at that date, when high-conductivity copper was not in demand, it may readily have been nearly 20 ohms.

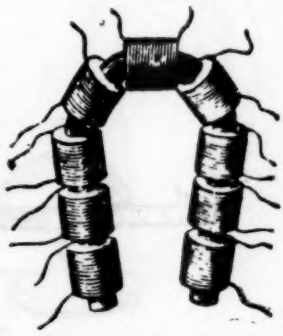

Figure 3.—Henry's electromagnet with group coils, for connection either in series or in parallel.

With an intensity battery of 25 zinc-copper cells in series and with the same active area of plate surface in each cell as before, the magnet lifted 8 ounces (227 gm.), with the whole length (320 m.) of copper wire inserted in the circuit; so that changing from 1 cell to 25 cells, increased the lift from 14 gm. to 227 gm., with the whole length of wire included. Short circuiting the long copper wire, or connecting the 25-cell series battery to the magnet terminals, gave no increase in lifting power. Indeed the lifting power observed was somewhat less (7 oz. or 198 gm.). It will be remembered, however, that the plain zinc-copper battery of those days was subject to marked polarization and variation of electromotive force, while in action. The effect of changing the battery from one cell to 25 in series, increased the lift from 14 gm. to 227 gm., with the long wire in circuit; but with the long wire cut out, the lift fell from 2,000 gm. to 227 gm. This was the first published demonstration of the importance of using a series-connected, or intensity battery, to increase the tractive power of an electromagnet of many turns through a considerable length of external circuit.

Discussing the remarkable power of the intensity battery to overcome the effect of inserting the 320 meters of extra copper wire in the circuit, Henry remarks:

> "On a little consideration, however, the above result does not appear so extraordinary as at first sight, since a current from a trough possesses more 'projectile force' to use Prof. Hare's expression, and approximates somewhat in intensity to the electricity from the common machine. May it not be a fact that the galvanic fluid, in order to produce its greatest magnetic effect, should move with a small velocity . . . ? . . . From these experiments it is evident that in forming the coil we may either use one very long wire, or several shorter ones as the circumstances may require; in the first case our galvanic combinations must consist of a number of plates so as to give 'projectile force', in the second it must be formed of a single pair."

Here Henry uses the term "projectile force" to designate what we call today *electromotive force* and "velocity of magnetic fluid" for

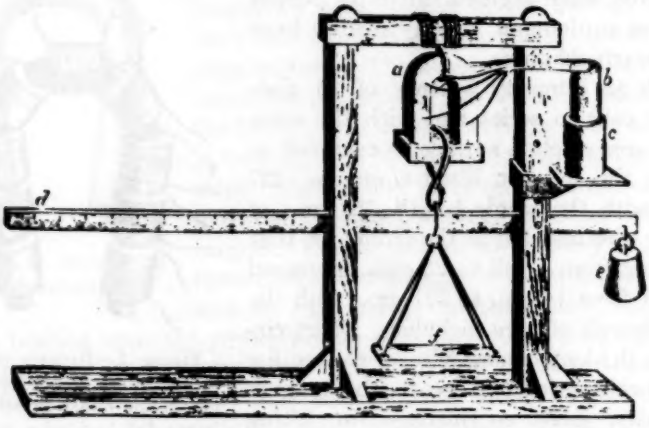

Figure 4.—Henry's frame for testing strength of electromagnet.

what we now call *current strength*. He is evidently not far from a conception of Ohm's law, which had already been formulated mathematically by Ohm four years before. By the term "trough" in the above quoted passage, Henry evidently means a series-connected battery, with the elements arranged in the form of a trough. Also by the term "common machine" he doubtless refers to either the frictional or the induction electric machine, which were the only electric generators known, prior to Volta's discovery, in 1800, of the voltaic pile.

In the same publication, Henry goes on to describe the construction of a larger electromagnet, a model of which, kindly loaned to us by the Smithsonian Institution from its museum, is shown here this evening.

The magnet had a winding of 9 coils of insulated copper wire arranged to be connected either in series or in parallel combinations. The total weight of the magnet was 21 pounds (9.5 kg.). It was excited by one zinc-copper dilute acid cell with concentric plates. The effects were tried of various winding combinations on the sustaining power of the magnet. The maximum was reached at 750 pounds (340 kg.), when all the windings were connected in parallel, or as a "quantity" winding. The magnet thus lifted more than 35 times its own weight, with the aid of a single exciting cell, a very remarkable achievement for the year 1831.

In a communication to Silliman's American Journal of Science[6] in April 1831, Henry describes a yet larger horseshoe electromagnet,

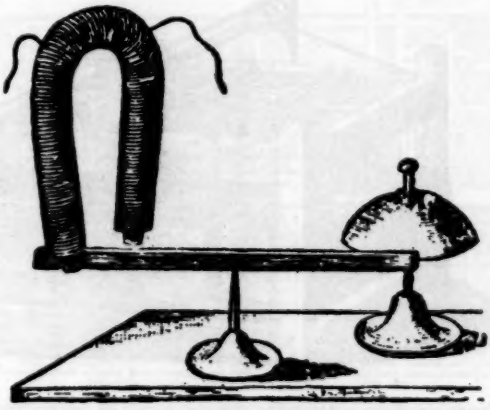

Figure 5.—Henry's bell-signal electromagnet.

constructed for Yale University. It weighed 59½ pounds (27 kg.) without its multiple-coil winding. Excited with a single zinc-copper dilute acid cell, it supported a weight of 2063 pounds (937 kg.).

Electromagnets for raising and carrying masses of iron are in fairly extended engineering use at the present day, and Henry's pioneering work at the Albany Academy from 1827 to 1832 clearly pointed the way to that electrical application.

The electromagnetic bell signaling instrument here shown, from the Smithsonian Museum collection of Henry apparatus, is a replica of an apparatus made and used by Henry, in 1832, for sending audible electromagnetic signals through a wire more than a mile in length. This apparatus is not referred to in Henry's paper of 1831, but appears in Henry's statement to the Board of Regents of the Smithsonian Insti-

[6] *An account of a large electromagnet, made for the laboratory of Yale College.* Bibliography 8, I: 50–53.

tution for 1857, together with testimony to show that the instrument was exhibited in 1832, at the Albany Academy.[7]

"I arranged around one of the upper rooms in the Albany Academy a wire of more than a mile in length, through which I was enabled to make signals by sounding a bell. (Fig. 7.)* The mechanical arrangement for effecting this object was simply a steel bar, permanently magnetized, of about ten inches in length, supported on a pivot, and placed with the north end between the two arms of a horse-shoe magnet. When the latter was excited by the current, the end of the bar thus placed was attracted by one arm of the horse-shoe and repelled by the other, and was thus caused to move in a horizontal plane and its further extremity to strike a bell suitably adjusted."

* Here Fig. 5.

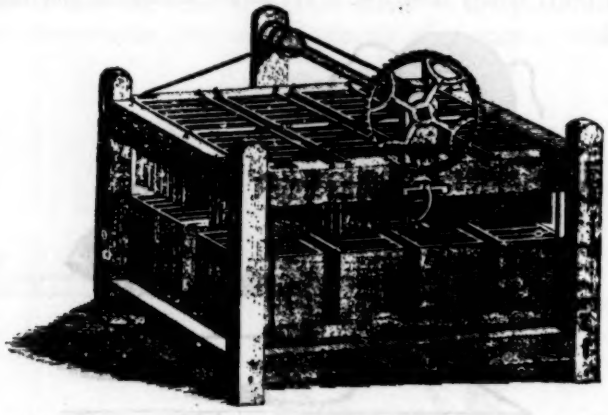

Figure 6.—Henry's voltaic battery for speedy change of connections between series and parallel.

The original Henry instrument is kept in the Palmer Laboratory Museum at Princeton, where Henry set it up, and is reported on good authority to have been used as a signalling device, in his house, on the Princeton University campus, operated by electric current from his laboratory, probably in the basement of Nassau Hall.

Henry declared that he never in his life filed an application for a patent of invention. In this technical sense, therefore, he was not an inventor; but in a broad sense of the term, he was undoubtedly a great inventor; because in making researches in basic science—his selected field of work—he often indicates through his writings that he realized from time to time possible applications for his discoveries, while leaving to others the tasks of introducing them into industrial

[7] *Statement in relation to the history of the electro-magnetic telegraph.* Smithsonian Annual Report for 1857, pp. 90–106. Bibliography 8, II: 420–437.

service. He always admitted that Morse was the inventor of the electric telegraph bearing that name, but Henry has recorded the following claims:[8]

"From a careful investigation of the history of electromagnetism in its connection with the telegraph, the following facts may be established:

(1) Previous to my investigations, the means of developing magnetism in soft iron were imperfectly understood, and the electro-magnet which then existed was inapplicable to the transmission of power to a distance.

(2) I was the first to prove by actual experiment that in order to develop magnetic power at a distance a galvanic battery of 'intensity' must be employed to project the current through the long conductor and that a magnet surrounded by many turns of one long wire must be used to receive the current.

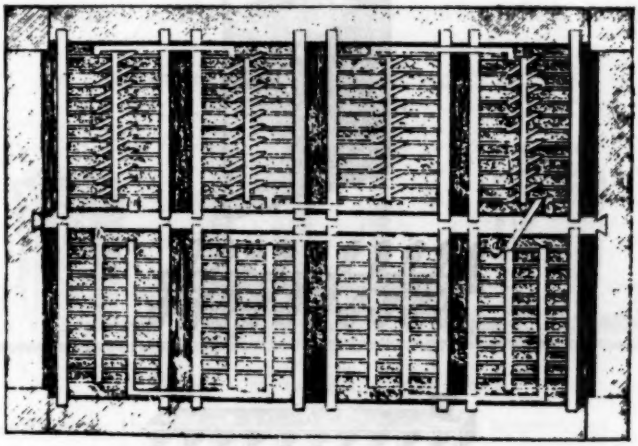

Figure 7.—Plan view of battery.

(3) I was the first to actually magnetize a piece of iron at a distance, and to call attention to the fact of the application of my experiments to the telegraph.

(4) I was the first to actually sound a bell at a distance by means of the electro-magnet.

(5) The principles I had developed were applied by Dr. Gale to render Morse's machine effective at a distance."

There can be no doubt that Henry's electromagnetic researches found abundant application in the magnetic telegraph.

Voltaic-Battery Mechanism for Series-Parallel Connections

Henry published in 1835, an illustrated description of a machine which he designed and constructed at Princeton for swiftly changing

[8] Bibliography 8, II: 435–436.

a voltaic battery of 88 cells, from series to parallel combinations, so that they might be, in the extreme cases, either all in series or all in parallel.[9] The various pairs of plates were held in a rigid wooden frame, and each plate had a little metallic cup fastened to it for holding a small quantity of mercury. Metallic bars of suitable size and shape, served to connect the cells in series or in parallel.

The same plan in essentials, is very generally employed today with storage-battery installations for charging them in parallel and discharging them in various series combinations for high-tension service.

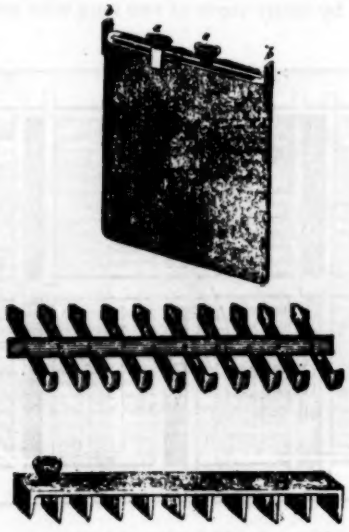

Figure 8.—Henry's voltaic cell and connectors.

Henry's apparatus was thus a pioneer form of voltaic-battery engineering design.

Electromagnetic Engine or Early Form of Electric Motor

On the table, is the replica of Henry's early form of reciprocating motor driven by voltaic-battery power. This replica is also loaned by the Smithsonian Museum. The original is preserved with the Henry apparatus at Princeton University.

The little engine is described by Henry in a letter to the Editor of

[9] *Description of a galvanic battery for producing electricity of different intensities.* Bibliography 8, I: 80–86. Trans. Am. Phil. Soc., 5: 217–222. Jan. 1835.

Silliman's American Journal of Science[10] published in July 1831, in the following terms:

> "Sir: I have lately succeeded in producing motion in a little machine by a power, which, I believe, has never before been applied in mechanics—by magnetic attraction and repulsion.
>
> Not much importance, however, is attached to the invention since the article, in its present state, can only be considered a philosophical toy; although, in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale may hereafter be applied to some useful purpose. But without reference to the practical utility, and only viewed as a new effect produced by one of the most mysterious agents of nature, you will not, perhaps, think the following account of it unworthy of a place in the *Journal of Science.*"

The apparatus consists of a pair of vertical permanent magnets, which, in modern parlance, are the *field magnets* of the little machine.

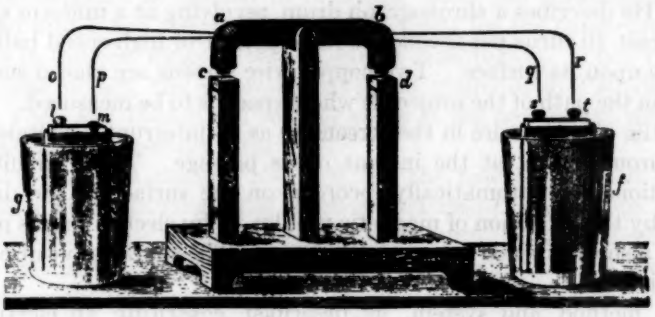

Figure 9.—Henry's electromotor device.

As described in the paper, their north poles are uppermost. A soft iron bar, pivoted about a horizontal axis, and wound with insulated wire, is free to oscillate over a certain range under the magnetic forces of the upright permanent magnets. This oscillatory electromagnet corresponds to the *armature* of a modern direct-current motor. At the free ends of the rocking armature are stiff projecting copper wires, arranged to dip into mercury cups at each end in such a manner that the current from a voltaic cell is caused to reverse the magnetization of the rocker bar near the end of each stroke, and so reverse the magnetic forces on the rocket bar. In this rocking commutator, we have the precursor of the *rotating commutator* of the modern motor.

Henry thus produced what was probably the first electric motor device using a commutator, although in the progress of the art, its

[10] *On a reciprocating motion produced by magnetic attraction and repulsion.* Bibliography 8, I: 54–57.

reciprocating motion had to be converted into rotary motion, before practical success was attained with motors.

Lightning Protection

Henry was a close observer of atmospheric electric phenomena, and contributed a number of articles to the literature of the subject at different times. He also, however, formulated a set of rules or directions[11] to be followed for the protection of houses from lightning. These rules would probably be regarded as good engineering specifications against lightning damage at the present date.

Electro-ballistics

In 1843, Henry communicated to the American Philosophical Society, a paper[12] *On a new method of determining the velocity of projectiles.* He describes a chronograph drum, revolving at a uniform speed of at least 10 turns per second, so as to permit of high-speed ballistic records upon its surface. Two copper wire screens are placed successively in the path of the projectile whose speed is to be measured. The projectile cuts the wire in the screens so as to interrupt a voltaic circuit through each, at the instant of its passage. These circuit interruptions are automatically recorded on the surface of the drum, either by the deflection of magnetic needles, or by electric sparks puncturing a sheet of ruled paper on the drum. The sparks are caused by induction coils.

The method and system, as described, constitute an electrical-engineering invention in ballistics.

MECHANICAL ENGINEERING

Testing of Building Materials

In August 1855, Henry read a paper before the American Association for the Advancement of Science, *On the mode of testing building materials.* The President of the United States had appointed a commission of five persons in 1851, "to examine the marbles which were offered for the extension of the United States Capitol" at Washington. Another commission of three persons was appointed in 1854, to repeat and extend some of the experiments. Henry was a member of both commissions and evidently took upon himself a large share of the experimental work.

Small cubical blocks of the marbles to be compared were tested in a

[11] *Construction of lightning rods.* Bibliography 8, II: 398–402, 1859. Also *On the protection of houses from lightning.* Proc. Am. Phil. Soc., June 20, 1845.

[12] Bibliography 8, I: 212–215. Proc. Am. Phil. Soc., 3: 165–167. May, 1843.

press for resistance to crushing. A long series of tests, made in this manner, brought out some remarkable and unexpected results. It was shown that when the crushing stress was exerted on the blocks with thin sheets of lead inserted between the press plates and the pressed block surfaces, the blocks gave way at about half of the pressure they could sustain when the lead sheets were not used. The account is, in effect, an engineer's report.

ACOUSTICAL ENGINEERING IN BUILDINGS

In the Proceedings of the American Association for the Advancement of Science[13] for August 1856, Vol. X, pp. 119–135, Henry published a remarkable paper, *On acoustics applied to public buildings*. He states that Prof. Bache and he had directed attention to the subject of acoustics as applied to buildings, when the President of the United States had referred to them the plans for the construction of rooms in the new wings of the Capitol at Washington. They visited, with this object, the principal halls and churches in Philadelphia, New York and Boston. The final plans of the new rooms were approved and successfully built.

They also had designs prepared for the new lecture hall of the Smithsonian Institution, and incorporated into them various acoustic principles their researches had brought out. These researches are most interestingly described in the paper. Henry, in this research, was an acoustical engineer, with his aim directed on improving the acoustic properties of the lecture hall. He was, however, also a pioneer investigator of interior acoustics, considered as a basic science. He says (p. 419):

> "These researches might be much extended; they open a field of investigation equally interesting to the lover of abstract science and to the practical builder."

In this passage is revealed that remarkable duality of Henry's mind which appears again and again in his writings. He studies a subject for a utilitarian purpose as an engineer, and enriches its basic science, while at another time he studies a new field as a physicist, and suggests intuitively to the reader where practical applications are likely to be found. He was *par excellence* a combination of physicist and engineer.

The acoustic properties of the Smithsonian lecture hall appear to have been very satisfactory, and to have endorsed the special acoustic features introduced into its construction.

[13] Bibliography 8, II: 403–421.

FOG-SIGNAL ACOUSTICS

Congress established the U. S. Lighthouse Board in 1852, with Henry as one of its members. Later, as chairman of its Committee on Experiments, he directed, in 1865, a series of acoustic researches on fog signals, that were not only of basic scientific importance, but also of great engineering value. He showed experimentally that beyond relatively short distances, artificial sound reflectors were of no avail. To eliminate the personal equation in acoustic observations of this kind, he describes an artificial ear or "phonometer," for making feeble sound waves perceptible to the eye.

These researches of Henry appeared as unsigned reports of the Light-House Board, but were subsequently included in his published papers. These reports contain comparisons of the acoustic ranges attained, under normal atmospheric conditions, by steam whistles, trumpets, and sirens. Such comparisons were made over short ranges by phonometer, and over long ranges by ear, on small vessels making exploratory trips for purposes of the test. They are acoustic-engineering reports of great interest. They were made at various times from 1865 to 1877.

In the course of these tests, Henry closely investigated the abnormal conditions of the appearance of fog signals at shorter and longer ranges, with their concurrent disappearance over a certain intermediate range, or belt of silence. These occasional but practically important acoustic anomalies, were referred to by Henry in two presidential addresses before your Society, one[14] on December 11th, 1872, when Dr. Tyndall was present, and the other[15]—his last address to you—on November 24th, 1877.

ILLUMINATING ENGINEERING

Light-House Development

In the Report of the Light-House Board for 1875, pp. 86–103, Henry points out that in 1852, when the Board[16] commenced its operations, sperm oil was the fuel generally employed. The steadily rising cost of sperm oil made it desirable to find some less expensive substitute. A series of experiments was commenced with lard oil, which

[14] *Remarks on some abnormal phenomena of sound.* Smithsonian Report 1878, pp. 490–496.

[15] *The method of scientific investigation and its application to some abnormal phenomena of sound.* Bull. Phil. Soc. Washington, **2**: 162–174.

[16] Bibliography 8, II: 477–510.

was then much cheaper, but not regarded as capable of use in powerful lamps.

Commencing with a pair of small conical lamps having "single-rope," as distinguished from tubular wicks, one burning sperm oil and the other lard oil, the two commenced nearly at equality of candlepower, by photometer; but after burning for three hours the lard-oil lamp fell to about one-fifth of the photometric power of the sperm-oil lamp. On analyzing the reasons for the falling off in candlepower of the lard-oil flame, Henry was led to the conclusion that the capillary flow or liquidity of the lard oil in the wick is relatively defective. This, however, was found to be affected by the temperature of the oil, so that by raising the temperature of the lard oil to about 250°F. the liquidity of the lard oil became greater than that of the sperm oil. When, therefore, the conditions of oil feeding through the wick of a large burner raised the temperature sufficiently, the lard oil should be capable of competing on favorable terms.

After further preliminary trials with larger tubular-wick burners, the experiment was carried to Cape Ann, Massachustts. Here were two twin light-houses, only 275 meters apart. One of these was operated with sperm oil, as usual, and the other with lard oil, each lamp being so trimmed as to exhibit its greatest capacity.

> "It was found by photometric trial that the lamp supplied with lard oil exceeded in intensity of light that of the one furnished with sperm oil. The experiment was continued for several months, and the relative volume of the two materials carefully observed. The quantity of sperm oil burned during the continuance of the experiment was to that of lard oil as 100 is to 104."

A long series of photometric measurements at Boston is then described, with the substitution of the Bunsen grease-spot photometer head for the earlier Rumford shadow comparator. An improved photometer for measuring the candlepowers of burners using different oils, was also set up at the Smithsonian Institution.

As a result of improvements in lamp mechanism, as well as in the substitution of lard oil for sperm oil in all of the light-houses of the United States, a great reduction was effected by 1866, in the annual cost of light-house oil.

This published account of light-house research is a fine engineering report, containing many basic scientific suggestions of great interest. Later on, the price of lard oil began to rise and a new series of researches was undertaken leading to the introduction of mineral oil, which was attended at first by a number of special difficulties.

METEOROLOGICAL ENGINEERING

Applications of Telegraphy

In our daily contact with the service of the Weather Bureau, which displays coastal storm warnings in advance of expected heavy gales, and furnishes daily weather forecasts, with maps, showing the principal meteorological conditions, at a given hour each day, over the North American Continent, it is hard for us to realize the corresponding conditions that existed, say, in 1845, before Henry left Princeton, and when there was no way of foretelling the approach of a coming big storm, except such as could be guessed by any single observer at one spot, and before the general laws of revolving storms had been arrived at.

Henry devoted much time to the study of meteorology, which evidently exerted a fascination for him throughout his life. The first page of his published papers gives abstracts of his first known scientific contributions (Proceedings of the Albany Institute in 1825 and 1826)—communications dealing respectively with *Chemical and mechanical effects of steam* and *Refrigeration by rarefaction of air*. Among his published papers are 38 that bear by title upon meteorology. According to the account by his biographer, W. B. Taylor, read before this Society October 26th, 1878, Henry's last feeble utterance on his dying day, May 13th, 1878 was a meteorological[17] enquiry.

Henry's early studies of weather, when he was at Albany, convinced him of the importance of securing simultaneous observations of barometric pressure, air temperature and humidity, wind velocity, cloud conditions and precipitation, at as many different stations as possible. In 1849, while the telegraph system of the country was only a few years old, it was organized with the aid of voluntary observers into a network by which a weather map could be made up each day at the Smithsonian Institution. Henry urged that every telegraph operator, coming on duty at a certain morning hour, should open with a definite meteorological message. This plan manifested its utility, but placed too heavy a burden on the Institution. In 1870, a meteorological office was established by the Government under the Signal Office of the War Department. This office was finally transferred to the Weather Bureau, created in 1891, under the Department of Agriculture. The early development of the Weather Bureau, was thus a telegraph-engineering development due to Henry's persistent labors in meteorology.

[17] Bibliography 2c. Smithsonian Coll., 21: 360.

CONCLUSIONS

From what has been above excerpted from Henry's writings, it will be seen that this many-minded man, who made so many notable contributions to basic science, also contributed much to applied science.

When, therefore, it is justly claimed for Joseph Henry that he was a scientist-discoverer, writer, organizer, and administrator, it can be confidently added that he was also an inventor and engineer.

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GEOLOGY.—*Tentative correlation of American glacial chronology with the marine time scale.*[1] C. WYTHE COOKE, U. S. Geological Survey.

When the great ice sheets crept down from the north during the Pleistocene epoch and covered Canada and parts of the northern States of the Union, they brought with them boulders and other spoil torn from the land across which they had pushed. At the southern end of each sheet, where the ice melted as rapidly as that behind advanced, great piles of débris accumulated in the form of terminal moraines or was swept onward by gushing rivers. Whenever the ice melted faster than it advanced, the ice front retreated northward and the ground beneath it was once more exposed to the weather. Soil formed, vegetation grew, and animals that had been driven away by the advance of the ice returned to graze, browse, or hunt.

After many years of intensive study of the glacial deposits, geologists have unravelled the tangled thread of Pleistocene history and have woven from it a brilliant tapestry depicting the interesting events of the Ice Age. They recognize a whole series of invasions of the ice each of which is separated from the preceding and succeeding invasions by long intervals of more or less complete deglaciation. Although there is not complete agreement among glacial geologists as to the details of what happened during the Pleistocene, most of them think that there were five principal periods of glaciation and that the last, the Wisconsin glacial stage, was marked by four separate advances of the ice. Altogether, therefore, there were at least eight glacial stages or substages and seven interglacial stages or substages.

While these battles between the forces of summer and winter were cutting their scars on the land, what was happening to the sea? Every ton of ice that was piled upon the land during the glacial stages came ultimately from the sea and was returned to it when it melted. Thus the level of the sea fell or rose as the continental ice caps waxed and waned. The comparatively short glacial stages were times of low water in the sea. During the much longer interglacial stages the

[1] Published by permission of the Director of the U. S. Geological Survey. Received April 18, 1932.

oceans overflowed their basins and flooded the low margins of the continents. The marks made by the sea on the continents during the glacial stages are now submerged, but the abandoned strand lines of the interglacial stages, flanking marine terraces, now stand above sea level. Eight such high strand lines have been detected along the Atlantic coast of the United States and in many other parts of the world.

The problem of correlating the glacial deposits with the marine Pleistocene terraces and strand lines is difficult of direct attack because the glacial deposits are best developed inland, far from the coastal terraces. Field studies in New Jersey and on Long Island, where

TABLE 1.—TENTATIVE AGE OF PLEISTOCENE TERRACES

Approximate altitude of strand line		Name of terrace	Glacial and interglacial stages
Feet	Meters		
270	82	Brandywine	Pre-Nebraskan warm stage
			Nebraskan glacial stage
215	66	Coharie	Aftonian interglacial stage
			Kansan glacial stage
170	52	Sunderland	Yarmouth interglacial stage
			Illinoian glacial stage
100	30	Wicomico	Sangamon interglacial stage
			Iowan glacial stage
70	21	Penholoway	Peorian interglacial stage
			1st Wisconsin glacial substage
42	13	Talbot	1st Wisconsin interglacial substage
			2nd Wisconsin glacial substage
25	8	Pamlico	2nd Wisconsin interglacial substage
			3rd Wisconsin glacial substage
12	4	Princess Anne	3rd Wisconsin interglacial substage
			4th Wisconsin glacial substage

late Wisconsin moraines cut across several terraces, may yield definite evidence as to the relative ages of the later members of the two series, but the earlier glacial deposits are not completely represented there.

An indirect method of arriving at tentative correlations of the two types of deposits is to compare the sequence of glacial stages with the sequence of strand lines and terraces. The latest Pleistocene strand line should correspond to the latest interglacial stage and each successively older strand should fit into its corresponding place in the glacial chronology. An attempt to do this was made in 1930[2] but the

[2] C. Wythe Cooke. *Pleistocene seashores.* This JOURNAL **20**: 389–395. 1930; *Correlation of coastal terraces.* Jour. Geology **38**: 577–589. 1930.

result was defective because the complete sequence of terraces and strand lines was then unknown. In order to make the two time scales fit it was necessary to recognize only two glacial substages within the Wisconsin although it was known that the Wisconsin is susceptible of division into four. A new attempt, shown in Table 1, utilizes the complete series of glacial stages and substages as well as all the Pleistocene strand lines now recognized by students of terraces. The two scales dovetail perfectly. There is no change from the 1930 correlation in the assignment of the older strand lines to a place in the glacial chronology, but additional terraces (the Talbot with a strand line at 42 feet, and the Princess Anne,[3] with a strand line at 12 feet) are inserted into the Wisconsin.

It can scarcely be expected that the tentative correlation here proposed will prove to be final or that it will soon receive general acceptance. It is merely offered as an improvement over that of 1930, which was admittedly highly speculative.

[3] In 1931 (this JOURNAL **21**: 513) I expressed doubt as to the validity of the Princess Anne terrace. On further investigation the terrace seems to be recognizable.

ZOOLOGY.—*A new coati from Nicaragua.*[1] E. A. GOLDMAN, Biological Survey.

Among mammals collected in eastern Nicaragua by Dr. Charles W. Richmond, many years ago, is a coati which seems to represent a subspecies that has been overlooked. General comparisons indicate marked contrast with its nearest congeners in color. The new form may be known by the following description:

Nasua narica richmondi subsp. nov.

Nicaragua Coati

Type.—From Escondido River, 50 miles above Bluefields, Nicaragua. No. 51331, ♂ adult, U. S. National Museum (Biological Survey collection), collected by Charles W. Richmond, November 19, 1892. Original number 158.

Distribution.—Humid tropical forested region of eastern Nicaragua, and probably adjoining parts of eastern Honduras, passing farther west into *Nasua narica bullata.*

General characters.—A large extremely dark-colored subspecies—darkest of the North American members of the group, with small teeth. Most closely allied to *Nasua narica bullata* of western Costa Rica, but still darker, black or very dark brownish black predominating over most of body, except where relieved by strongly contrasting white markings; cranial characters distinctive. Similar to *N. n. narica* and *N. n. yucatanica* of Mexico, but much darker colored than either and differing from both in combination of cranial characters.

[1] Received April 13, 1932.

Color.—Type: General color of upper parts very dark brownish black, unmodified over top of head and on posterior part of back, rump, and thighs, but finely flecked with light buff across anterior part of back, the flecking involving only extreme tips of hairs, changing gradually to tawny between shoulders; outer sides of forearms overlaid with silvery white, the long white tips of hairs here contrasting strongly with the dark general body tone; under parts in general very dark brownish black, pure along median line of abdomen, dark brown mixed with white on chest, under side of neck and inner sides of forearms; white facial markings as usual in the group, but light lines between eyes narrow and inconspicuous; ears broadly edged with white; feet deep glossy black; tail very dark brownish black with scarcely a trace of annulations discernible.

Skull.—Similar to that of *N. n. bullata*, but more slender; rostrum and interorbital region narrower; teeth, especially the molars, and posterior premolars smaller; audital bullae large and fully inflated as in *bullata*. Approaching that of *N. n. narica*, but larger; audital bullae relatively larger, more fully inflated; dentition similar, but posterior premolars smaller. Compared with that of *N. n. yucatanica* the skull differs in decidedly larger general size, and relatively larger, more inflated bullae.

Measurements.—Type: Total length, 1,190 mm.; tail vertebrae, 630; hind foot, 109. *Skull* (type): Occipitonasal length, 132.9; condylobasal length, 129.8; zygomatic breadth, 75.2; interorbital breadth, 28.5; crown length of three large posterior cheek teeth (posterior premolar and molars), 21.8; crown width of posterior premolar, 7.1.

Remarks.—The very dark coloration of *Nasua narica richmondi* is a character shared in common with the regional representatives of several other groups of mammals. In cranial characters *richmondi* is somewhat intermediate between the larger more robust subspecies, *N. n. bullata*, and the smaller slenderer form, *N. n. yucatanica*.

Specimens examined.—Two, from Nicaragua as follows: Escondido River (50 miles above Bluefields), 1, (type); Segovia River, 1.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

482ND MEETING

The 482nd meeting was held in the Cosmos Club, November 25, 1931, President MEINZER presiding.

Program: MARIUS R. CAMPBELL: *The alluvial fan of Potomac River.*—The great deposit of gravel on the peninsula which projects southward between the Potomac and Patuxent rivers and to which the name Brandywine was given by William B. Clark, instead of being a marine deposit as has heretofore been supposed, is a great alluvial fan built of gravel and sand brought down by the Potomac River. The distinctive material is fossiliferous chert which is not available for transportation by any other river in this region. This chert was traced from Anacostia to Point Lookout, Md., and thence across the Potomac River to Warsaw and Rappahannock, Va. and as far south as Urbana on the Rappahannock River. The area covered is at least 70 miles long and 40 miles wide in the widest part. It was deposited when the Rappahannock River had a course different from that which it has at present and when sea level was approximately 100 feet higher than it is today. (*Author's abstract.*)

Discussed by MISS BASCOM and MR. STOSE.

G. F. LOUGHLIN and A. H. KOSCHMANN: *Dissected pediments in the Magdalena district, New Mexico.*—The Magdalena district, New Mexico, is in the southeast part of the Basin and Range Province. It includes the north end of the Magdalena Range and Granite Mountain, which consist of tilted and faulted sedimentary rocks of Carboniferous age and volcanic rocks of Tertiary age on a pre-Cambrian basement. The lava flows originally extended across the present valleys and over the Magdalena Range, but the earliest stages of erosion swept the volcanic cover from the main range, completely in the northern part, but only partly south of the town of Kelly.

The Magdalena Range and Granite Mountain are bounded on the east and on the west by extensive plains, which have been found to be pediments covered by a veneer of alluvium. The foot-hills and lower slopes of the range include many flat and gently westward sloping spurs and benches which are interpreted to be remnants of older, dissected pediments. Some of them are still capped by patches of alluvium or remnants of old landslides. The more abundant and better defined benches are grouped at six different levels. Others at still higher levels may also represent old pediments, but are too few to be convincing.

The uplift of the range was accompanied by extensive faulting, and the present valleys are in areas of the down-warped and down-faulted volcanic formations that were most readily eroded; but no appreciable amount of faulting has taken place recently enough to account for any of the better defined benches.

The dissection of the pediments is attributed to the general lowering of the Magdalena Plain, due to the tapping of its drainage lines by San Lorenzo and La Jenze Creeks, which are tributary to the Rio Grande. The development of the different stages of erosion, marked by the rock benches and the high and low alluvium, is believed to be related to the varying rates at which these streams cut their ways downward through the volcanic flows and tuffs that lie east and northeast of the Magdalena Range; but, owing to insufficient information regarding the history of the Rio Grande Valley, definite correlation must await further study. (*Authors' abstract.*)

Discussed by Messrs. ATWOOD, PARKER, HUNT, HEWETT, and LOUGHLIN.

E. T. ALLEN: *Geysers.*—Geysers are by no means as well known as is generally supposed. Such important characteristics as: (1) an intermittent rise and fall of the water level in many geysers, (2) an intermittent discharge in many, (3) common association with a surface layer of superheated water, and (4) the frequent occurrence of a maximum temperature before the bottom of the geyser well is reached remain either undescribed or little known.

The original theory of geyser action proposed by Bunsen and Descloizeaux left out of account an influx of colder water after every eruption which alone can explain periodicity (Lang). Bunsen and Descloizeaux's principal contention that temperatures at every depth in the geyser well increase steadily with time between eruptions is not supported by their data (Thorkelsson). It is difficult if not impossible to reconcile the facts with the Bunsen and Descloizeaux theory; only by the assumption of a side chamber connected with the geyser well by a narrow channel, a chamber in which geyser action originates, can this be done.

Data from the Yellowstone Park were presented in support of Lang's hypothesis, that a geyser may become extinct through steam leakage in the side chamber. On the assumption that the heat supply of geysers is transported by jets of magmatic steam through seams in the rock, the life of a geyser might be ended by a diversion of a local supply to other quarters by the gouging out of new passages by the solvent action of hot water.

The erratic variations in geyser behavior are certainly not due to seasonal changes, but so far they remain entirely unexplained. (*Author's abstract.*)

Discussed by Messrs. MATTHES, JOHNSTON, RUBEY, ALDEN, and FENNER.

483RD MEETING

The 483rd meeting was held at the Cosmos Club, December 9, 1931, Vice-President F. L. HESS presiding.

Program: O. E. MEINZER delivered his presidential address: *History and development of ground water hydrology.*

39TH ANNUAL MEETING

The 39th annual meeting was held at the Cosmos Club after the adjournment of the 483rd regular meeting, President O. E. MEINZER presiding. The annual report of the secretaries was read. The treasurer presented his annual report showing an excess of assets over liabilities of $1,357.02 on December 6, 1931. The auditing committee reported that the books of the treasurer were correct.

The results of balloting for officers for the ensuing year were as follows: *President:* F. E. MATTHES; *Vice Presidents:* F. L. HESS and H. G. FERGUSON; *Secretaries:* J. F. SCHAIRER and W. H. BRADLEY; *Treasurer:* C. WYTHE COOKE; *Members-at-Large of the Council:* FRANK REEVES, T. B. NOLAN, E. P. HENDERSON, F. G. WELLS, and C. E. RESSER; *Nominee as Vice President of the Washington Academy of Sciences representing the Geological Society:* O. E. MEINZER.

C. H. DANE, J. F. SCHAIRER, *Secretaries.*

484TH MEETING

The 484th meeting was held at the Cosmos Club, January 27, 1932, President MATTHES presiding.

Program: CHAS. B. HUNT: *The junction of three orogenic types in New Mexico.*—Three orogenic types are represented in an elongate belt of country lying midway between Albuquerque and Mt. Taylor, New Mexico. The exposed rocks are of Upper Cretaceous age and consist of the Mancos and Mesaverde formations which intertongue. The main body of the Mancos underlies the Mesaverde and is underlain by the Dakota (?) sandstone.

Three physiographic provinces, the Colorado Plateau, the Southern Rocky Mountains, and the Basin and Range, each with a distinctive type of structural deformation, come together in this area.

The southeast border of the Colorado Plateau consists of little faulted and gently folded strata. The Nacimiento Mountains of the Southern Rocky mountains are an anticlinal uplift, asymmetric in cross section with the steep flank to the west. A reverse fault has been reported along the west flank. The uplifting probably ended in the Miocene. The Rio Grande valley belongs to the Basin and Range province and consists of blocks separated by faults having parallel trends. So far as known all the faults are normal. The major faults attain a maximum displacement of 3500 feet. The few exposures of striae found on the fault faces indicate vertical rather than horizontal movements. The major faults produce a stepdown to the west, and most of the fracture surfaces dip west as low as 45°. The strata dip east generally between 10° and 20°. Locally the dip increases to nearly 40°. The structural level of the Colorado Plateau is considerably higher than the Basin and Range which has been dropped down by faulting and monoclinal folding.

The deformation of the Basin and Range province in this area ended in the Miocene and therefore is probably contemporaneous with the uplifting of the Nacimiento Mountains.

The dominant regional fold of the Rio Grande valley at Albuquerque in the Basin and Range province is an anticline which is the southward continuation of the Nacimiento anticline. It was a growing uplift during the middle Tertiary as was the uplift of the Nacimiento Mountains. The anticline in the valley collapsed by means of block faulting during the process of uplifting. Both the faulting and the uplifting ceased in the Miocene. (*Author's abstract.*)

Discussed by Messrs. KING, HEWETT, PARKER, L. A. SMITH, RESSER, and MATTHES.

W. T. SCHALLER: *The crystal cavities of the New Jersey zeolite region.*—The regular crystal cavities associated with zeolitic rock in the trap rock quarries in and near Paterson are evidence of the former existence of crystals of minerals, now dissolved away.

The geological features indicate that the trap rock lava flowed into a Triassic lake rich in glauberite, a sulphate of sodium and calcium. These constituents, dissolved by the heated waters and mixed with the molten rock, crystallized out in the lava as anhydrite whose later solution formed rectangular cavities, and as glauberite, which formed rhombic cavities. Some of the lamellar cavities may be due to lamellar calcite crystals, which crystal habit, tabular parallel to the base, is the high temperature crystal form of calcite.

Anhydrite has been found in the trap rock in rectangular crystals, partly changed to gypsum and to thaumasite and partial and complete removal of these alteration products has formed rectangular cavities. Infiltration pseudomorphs of quartz in some of the rhombic cavities have yielded cores bounded by crystal faces whose angular values are those of glauberite.

Babingtonite, which has been suggested as the original mineral of the cavities, does not agree in its crystallography and cleavages with the shapes of the cavities. Moreover, its period of formation is much later than the minerals forming the cavities. (*Author's abstract.*)

PARKER D. TRASK: *Relation of calcium carbonate content of sediments to salinity of the surface water.*—Salinity appears to be an important factor in the deposition of calcium carbonate in marine sediments. A statistical study of 3,000 samples from all parts of the world shows that temperature and depth of water being constant, the carbonate content of the deposits varies with the salinity of the surface water. Sediments accumulating in regions in which the surface salinity is less than 34 parts per thousand, as a rule contain little carbonate and those forming in areas in which the salinity is greater than 35 parts per thousand generally contain considerable carbonate. The critical salinity is about 35 parts per thousand. This relation holds for both near-shore and pelagic sediments, but pelagic deposits for given salinities contain more carbonate than do near-shore sediments.

Temperature and depth of water appear also to influence the deposition of carbonate, but the effect of surface temperature and of depths less than 1500 fathoms seems to be less than that of salinity. In pelagic areas, depths greater than 1500 fathoms probably affect the carbonate content slightly more than does salinity.

Carbonate deposition almost certainly is influenced to a considerable extent by the activity of living organisms, but this phase of the problem was not investigated particularly. However, if organisms are the dominant factor

in carbonate deposition, it seems evident from the data compiled that their activity to some, and perhaps to a considerable, extent depends on salinity, especially on variations between 34.5 and 35.5 parts per thousand.

The chief geologic interpretations of the data presented in this paper are (1) that if a recent marine sediment contains less than 2 per cent $CaCO_3$ the chances favor its having been deposited in brackish water or in a region of subnormal salinity; and (2) that if a sediment has more than 50 per cent carbonate, that is, if it is a limestone-forming deposit, it probably accumulated in water having a salinity greater than normal. These generalizations indicate probabilities in the sense of mathematical odds. That is, if 100 random samples were chosen, considerably more than 50 of them would accord with the generalization expressed. However, not all of the hundred samples would agree with it; because salinity is only one of several factors affecting the accumulation of carbonate, and in any individual environment it is possible for other factors to mask the influence of salinity.

If carbonate deposition in the geologic past was governed by the same conditions as at present, climate in some places may have played an important part in the deposition of carbonate. For example, in some epicontinental seas whether or not the deposits would be calcareous might depend to a considerable extent upon whether the loss of water by evaporation was greater or less than the addition of water by rainfall or from land. That is, alternations between limestone and shale or between calcareous and non-calcareous shale in some places may have been caused more by changes in climate than by shifts of strandline. This hypothesis is not presented as indicating the general rule, but as only one of the factors to be considered in the interpretation of the conditions of deposition of sediments of past geologic age. (*Author's abstract.*)

Discussed by Messrs. R. C. WELLS, VISCHER, SCHAIRER, PARKER, BRAMLETTE, WOODRING, RUBEY.

485TH MEETING

The 485th meeting was held at the Cosmos Club, February 10, 1932, President MATTHES presiding.

Program: W. D. JOHNSTON, JR.: *Structure of the Grass Valley batholith, California.*—A small granodiorite batholith—5 miles long and ½ to 2 miles wide—on the western slope of the Sierra Nevada Mountains offers unusual opportunity for structural study by means of the extensive mine workings which penetrate the intrusion to a vertical depth of 3700 feet below the surface and follow vein fractures underground for over two miles along the strike. Lindgren, Howe, and Knaebel have described the Grass Valley gold quartz deposits and considered the structural relations as a whole.

With the exception of the Idaho-Maryland group which are localized by the serpentine-diabase contact in the host rocks, the veins are roughly parallel with the margins of the batholith and the principal veins dip into the granodiorite at an average angle of 35 degrees. A second set of veins, less in number and in gold values, form a conjugated system with the former. All measurable displacements on the veins are thrusts. Together the two series of veins define the planes of maximum shear resulting from compressive stresses operating along a horizontal axis normal to the long axis of the batholith.

A series of almost vertical fractures, locally called "crossings" of approximately the same age as the vein fractures strike in the northeast quadrant, transverse to the long axis of the batholith. Many of these fractures are occupied by acidic and basic dikes.

In the mechanical conception of igneous intrusives developed by Cloos the veins occupy marginal thrusts and the conjugated back-dipping shear plane and the "crossings" are tension or q cracks.

If the original mechanical system be viewed by means of a strain ellipsoid the axis of maximum pressure lies in a horizontal plane normal to the long axis of the batholith, the intermediate pressure axis is horizontal and parallel with the long axis of the batholith and the axis of minimum pressure is vertical.

Prior to quartz mineralization the vertical tension cracks were closed and subsequent relief from compressive stresses was upward, resulting in the opening of the vein fractures for the deposition of quartz. (*Author's abstract.*)

Discussed by Messrs. FERGUSON, RAY, HEWETT, and L. H. SMITH.

W. H. BRADLEY: *Erosion surfaces on the north flank of the Uinta Mountains.* —Long remnants of the Bishop erosion surface capped by the Bishop conglomerate extend northward from the north flank of the Uinta Range. This surface which rises from an elevation of about 7,300 feet out in the basin to nearly 13,000 feet near the crest of the range is interpreted as a pediment formed under an arid or semi-arid climate by the lateral corrasion of a group of graded streams controlled by a common base level. The Bishop conglomerate is interpreted as a deposit formed in response to a shift in climate toward greater aridity than prevailed while the underlying surface was being cut.

About 400 to 500 feet below the remnants of the Bishop pediment are remnants of another pediment formed in essentially the same manner. This is the Browns Park pediment or surface, remnants of which are covered by the Browns Park formation at the east end of the Uinta Range. The Browns Park and Bishop surfaces were formerly thought to be equivalent, but the Bishop surface has now been traced eastward and correlated with the nearly level top of Cold Spring Mountain which in turn lies about 500 feet above an undisturbed remnant of the Browns Park surface. Thus the Bishop conglomerate is older than the Browns Park formation whose age is now regarded as late Miocene or early Pliocene.

After the deposition of the Browns Park formation the east end of the Uinta Range collapsed. Into this graben the Green River was diverted, probably by a combination of piracy and warping. It then flowed on the uppermost beds of the Browns Park formation and apparently was soon thereafter captured by the headward erosion of a tributary to Pot Creek which drains Summit Valley. This capture diverted it so as to flow across the main Uinta Range along the site of Lodore Canyon. Heretofore the course of the Green River through Lodore Canyon has been regarded as superposed from the Browns Park formation. (*Author's abstract.*)

Discussed by Messrs. MATTHES, SEARS, and ALDEN.

HUGH S. SPENCE (Mines Branch, Department of Mines of Canada): *Pitchblende deposits at Great Bear Lake, Canada.*

Discussed by Mr. HESS.

486TH MEETING

The 486th meeting was held at the Cosmos Club, February 24, 1932, President F. E. MATTHES presiding.

Informal communications: Mr. D. F. HEWETT read a letter from Chester

Washburne who suggested the generalization that normal fault surfaces are concave toward the downthrown side (the active side) in regions of igneous activity and concave toward the upthrown side (the active side) in regions remote from igneous activity.

Discussed by Messrs. A. KEITH, J. C. RAY, and P. J. SHENON.

Program: N. H. DARTON: *Some Algonkian strata in Arizona and adjoining regions.*—The purpose of this paper is to show that most of the strata of the Apache group of central Arizona are unconformably overlain by sediments containing fossils of Middle and Upper Cambrian age and are very closely similar to the Unkar and Chuar groups of the Grand Canyon. The stratigraphic succession in the two regions is, however, somewhat dissimilar. The Dripping Spring quartzite and associated shale and conglomerates and the overlying Mescal limestone which constitute a large part of the Apache group have all the striking characteristics of the Shinumo quartzite, Bass limestone, and red Hakatai shales, of the Unkar group as exposed in the Grand Canyon. The peculiar intrusive diabase sills conspicuous in both areas are remarkably alike. They are all pre-Cambrian and have caused the development of crysotile bodies in certain impure members of both the Mescal and Bass limestones which they invade. These two formations contain a large amount of algal material, which according to recent observations by Resser and Stoyanow also occurs in abundance in some members of the Chuar group. The Mescal limestone, which is an important ore carrier in the Old Dominion Copper Mine at Globe, is overlain in many places by a thin flow of vesicular basalt similar to those in the Chuar group. This is overlain unconformably by sandstone with local conglomerate containing fragments of the old lava. This overlying sandstone, which is the Troy or top formation of the Apache group, has yielded Cambrian fossils which will soon be described by Dr. Stoyanow of the University of Arizona. He has found them not only in the upper member in which I discovered the Abrigo fauna some years ago, but also in the lower beds where in places they are of Middle Cambrian age. The relations of these sandstones vary in different parts of the region but to the southeast they have been traced into the Bolsa quarztite which underlies the Martin (Devonian) limestone. It is now proposed to limit the application of the term Apache group to the Mescal and underlying strata.

The Millican formation in the region about Van Horn, Texas, with its diabase intrusions, algal limestones, red shale, and quartzites is somewhat similar to the Apache group. The Lanoria quartzite in Franklin Mountains near El Paso with its diabase intrusions also presents features of resemblance and similarity of history to the exposures in Arizona. The Mazatzal and some other quartzites in Arizona and New Mexico are probably earlier. (*Author's abstract.*)

Discussed by Messrs. RESSER, HEWETT, and KING.

ERNST CLOOS: *Is the Sierra Nevada batholith a batholith*?—A structural survey of the Sierra Nevada batholith, between Mono Lake and the Mother Lode, was carried out in 1930–1931. The methods applied were those described by Hans Cloos, Robert Balk and others.

The Sierra Nevada intrusive body was found to be a composite mass, of which the components show their own structural individuality. The first intrusions took place along tectonic or stratigraphic boundaries; the following ones preferred the boundary between previous intrusions and the wall rock. The contacts usually dip steeply, generally *under* the batholith, but near Mariposa, the inward dip is only 30 to 40 degrees. A very intense flow structure follows the contacts, closing to an arch or dome in the center. The

dome shape is believed to be caused by retardation of the semiliquid magma during its rise along the contacts. Joint fans were formed at a later stage, indicating the continuance of the upward movement during consolidation of the magma. Marginal thrusts along the contacts effected an upward elongation of the margins. Thrusts, following the Mother Lode Zone were formed in a similar way and indicate a close relationship between the Mother Lode structure and the batholithic intrusion.

No signs of differentiation in the present magma chamber were found. All partial intrusions show clear contacts and a pure composition from one contact to the other. Differentiation of these magmas must have taken place in greater depths. No assimilation contacts, signs of convection currents, or traces of sinking blocks were observed.

To judge from the available data, the Sierra Nevada batholith does not seem to be a true batholith, in the sense of Suess or Daly. A succession of intrusions, beginning in the area of the Mother Lode Zone, opened and gradually widened a gap. The first intrusions preferred stratigraphic or tectonic boundaries. Those following took advantage of the boundaries between previous intrusions and the wall rock.

The regions of uniform internal structure grew gradually with increasing rigidity. The *schlieren* dome is overlapped by an arch of flow lines. The latter is overlapped by joint fans. As the rigidity increased, regional joints became more and more important, until finally the whole area between the eastern fault and the Mother Lode reacted as one block. (*Author's abstract.*)

Discussed by Messrs. MATTHES, FERGUSON, and CLOOS.

J. F. SCHAIRER and W. H. BRADLEY, *Secretaries.*

SCIENTIFIC NOTES AND NEWS

At the dinner of the National Academy of Sciences on April 26, the Mary Clark Thompson Medal was presented to Dr. DAVID WHITE, U. S. Geological Survey, the presentation address being made by Professor WILLIAM B. SCOTT, of Princeton University.

The John Price Wetherill Medal has been awarded by the Franklin Institute to Dr. FRANK WENNER of the Bureau of Standards "in consideration of his ingenious design of a recording teleseismograph of superior performance."